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Measuring temperature of the atmosphere in the steelmaking furnace

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ABSTRACT

The paper presents a measurement of temperature in a steelmaking furnace with an oxygen refining process, specifically in a tandem furnace. Knowledge of the temperature is important for optimizing the manufacturing process and extending of the life cycle of the inner furnace lining. Conditions in the furnace are very demanding; the temperature may temporarily exceed 2000 °C and exhibits changes of 60 °C s^{-1}. The atmosphere in the furnace is mainly oxidizing and its chemical composition is very variable. In the atmosphere there are also present liquid and solid compounds which act chemically and abrasively on the lining and on the sensor. These conditions make it impossible to use a suction pyrometer, contactless optical or acoustic measurement methods. It was decided to use a thermocouple in a protective tube. The sensor was inserted into the furnace through a steel bushing with water cooling. For the first measurement the type B thermocouple in Al_2O_3 protective tube inside an outer shielding tube made from SiC was used. The second sensor used the type C thermocouple in a special thick-walled protective tube made from sintered SiC. The sensor does not measure the temperature of the gas itself, since it is affected by radiation of the surrounding areas. Conditions for heat transport from the furnace to the sensor are variable and difficult to determine; therefore, the accurate identification of the atmosphere temperature is not possible. Limit values of the temperature interval of the atmosphere were determined, for hypothetical cases of athermanous and ideally diathermic atmospheres.

1. Introduction

Steel is produced at high temperatures when the temperature of the molten steel itself is about 1600 °C and temperatures in the working space of the steel manufacturing aggregates (an oxygen converter, a tandem furnace or an electric arc furnace) are even higher. For this reason, the demands on the internal refractory lining of these aggregates are very high. The lining gradually degrades and wanes, while the cost of the renewal is significant. Another negative effect on the lining, in addition to high temperatures, is the corrosive effect of the furnace atmosphere, which is more intense at high temperatures. The adverse impact on the life cycle of ceramic linings is also caused by cyclical temperature changes triggered by the nature of the batch of the steel production technology (in contrast, for example, to the blast furnace).

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For these reasons, it is very useful to measure the temperature in a working space of the furnace in order to optimize the production technology. However, generally speaking, this is a very challenging task, whether it comes to a temperature measurement of the furnace atmosphere, or to a measurement of the temperature of the lining.

The temperature of the furnace atmosphere could be, especially for production units based on the oxygen process (a tandem furnace and an oxygen converter), an important indicator of the ongoing technological process regularity. At the same time, knowing the temperature can serve as information characterizing a "thermal load" of the lining. The problem is how to measure the temperature in practice while protecting the sensor from temperature and corrosive effects of the furnace atmosphere. The temperature measurement of gases is a difficult task in general, but in the case of the steel furnace the measurement is greatly complicated due to an extreme pollution of the furnace atmosphere. For the purpose of the development and experimental tests of the sensor, the tandem furnace was chosen. The objective was to measure the temperature just below the crown of the furnace.

2. Description of measurement conditions in a tandem furnace

The tandem furnace consists of two furnace hearths: preheating and refining (Fig. 1). Each hearth is equipped with an obliquely retractable refining oxygen nozzle and another nozzle inserted from above for post-combustion of carbon monoxide (CO). The furnace is closed by a crown from above, which is composed of panels, allowing for a quick replacement. Lining consists of hanging fired refractory magnesia–chrome bricks. Both hearths are connected by a channel that allows flowing exhaust gases from the preheating into the refining hearth. The flue gases with high content of CO are produced in the refining hearth, and are subsequently post-combusted in the preheating hearth. Fumes from the preheating hearth are discharged into the exhaust. The functions of both hearths alternate. Refining time takes ideally about 70 min, the entire time of the cycle, which includes preheating and refining, practically takes about 160 min.

According to preliminary approximate calculations, the combustion temperature of the atmosphere in the tandem furnace may temporarily exceed 2000 °C. Preliminary measurement which used a platinum thermocouple, confirmed that the temperature in the connecting channel and in the exhaust temporarily exceeded 1800 °C. At the same time, the upper limit of the measuring instrument range has been reached and, moreover, destruction of the thermocouple occurred. Additionally, it was shown that the flue gas temperature has significant fluctuation reaching almost 40 °C s^{-1} in the connecting channel and almost 60 °C s^{-1} in the exhaust. These temperature fluctuations have an undesirable effect both on the lining and on the sensor.

The chemical composition of the furnace atmosphere is highly variable in time. The concentration of CO in the exhaust of the preheating hearth ranged from 0 to 25 vol% (an average of 1.7 vol%) during preliminary measurements, the CO_2 concentration ranged from 0 to 33 vol% (an average of 9 vol%), and the O_2 concentration ranged in the interval from 0 to 21 vol% (an average of 16 vol%). The correlation analysis showed that CO_2 and O_2 are related inversely (the Pearson's correlation coefficient was negative −0.45), similarly, but more weakly related CO and O_2 (the correlation coefficient was −0.12), whereas the correlation between CO_2 and CO was directly proportional (the correlation coefficient was 0.7).

It follows from the above data that there is a predominantly oxidizing atmosphere in the tandem furnace which can, however, temporarily change into reducing.

In the atmosphere, aside from the analyzed gases, are present also other gaseous, liquid and solid compounds, in particular FeO, CaO, MgO, possibly also graphite, Al_2O_3, SiO_2, Cr_2O_3 and other which act both chemically and abrasively on the lining, and hence on the temperature sensor. These components also cause the formation of smoke in the atmosphere, which significantly affects heat transport by radiation.

The dynamic effect of the flowing gas on the sensor should not be neglected either. While designing the sensor, mechanical effects of the furnace vibrations and shocks as well as movement of the lining in case of the furnace tilting during tapping needed to be taken into consideration.

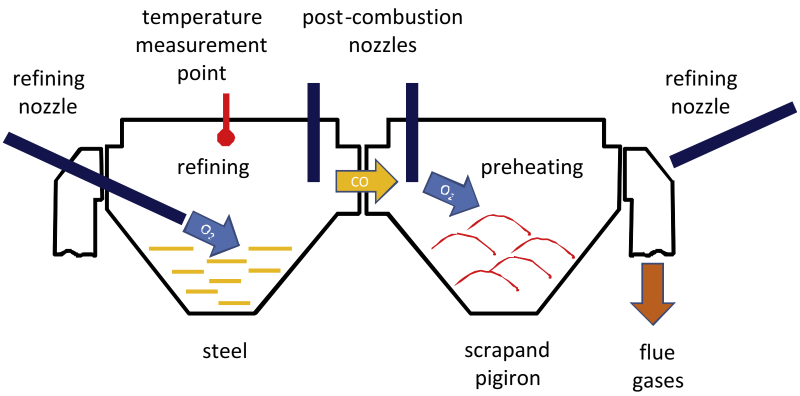

Fig. 1. Diagram of the tandem furnace.